Zooplankton Aggregation Near Sills

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LONG-TERM GOALS

Improved knowledge of the physical and biological mechanisms and interactions responsible for forming and maintaining aggregations of biological sound-scatterers in the ocean.

OBJECTIVES

Dense aggregations of plankton and fish often occur in localized regions where ocean currents interact with steeply-sloping seabed. These sites are ecologically important 'hot spots' for prey-predator trophic interactions, and are also zones of very strong acoustic backscatter. Our project examines the biological and physical mechanisms responsible for forming, maintaining and dispersing zooplankton aggregations near the sill of Knight Inlet, a large fjord in British Columbia (sill at 50º41'N 126º00'W).

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APPROACH

Our field sampling is multidisciplinary, linking fine-resolution acoustic data with *in situ* physical and biological measurements. Sampling tools included: ship-mounted multi-frequency acoustics to map cross-sill vertical and horizontal distributions of backscatter intensity and horizontal velocity (drift + swimming); an instrumented multiple plankton net (BIONESS) and an optical plankton counter (OPC) for zooplankton abundance, species composition, and body size/shape; ZOOVIS: a high resolution digital camera for zooplankton body/swimming orientation; CTD and transmissometer to describe temperature, salinity, and turbidity fields; and a moored acoustic Doppler current meter (ADCP). This component of the project focused on the application of ZOOVIS to quantify the distributions, abundances, and orientations of euphausiids around the sill and elsewhere in the fjord.

ZOOVIS (Fig. 1) is a tethered instrument consisting of an underwater platform that incorporates a down-looking 4.2 Mpixel, 14 bit monochrome digital camera that images the contents of a defined volume of water illuminated by a strobed light sheet. A CTD including a fluorometer and transmissometer measures hydrographic parameters. The underwater platform is connected by an electro-optical tether that supplies power and carries data. Images from the camera and data from the CTD are sent to an embedded PC that is networked to a surface PC. The camera system can be adjusted to image different volumes of water and both the camera housing and the strobe are mounted on worm-gears that allow rapid focusing. In 2002 we imaged volumes ranging from 300-3400 ml per image. Acoustic data from the ship-mounted echosounders is used to guide ZOOVIS into acoustic scattering features of interest. ZOOVIS can be used as a profiling instrument, however we normally towed it at 1-2 kts in tow-yo or horizontal modes.

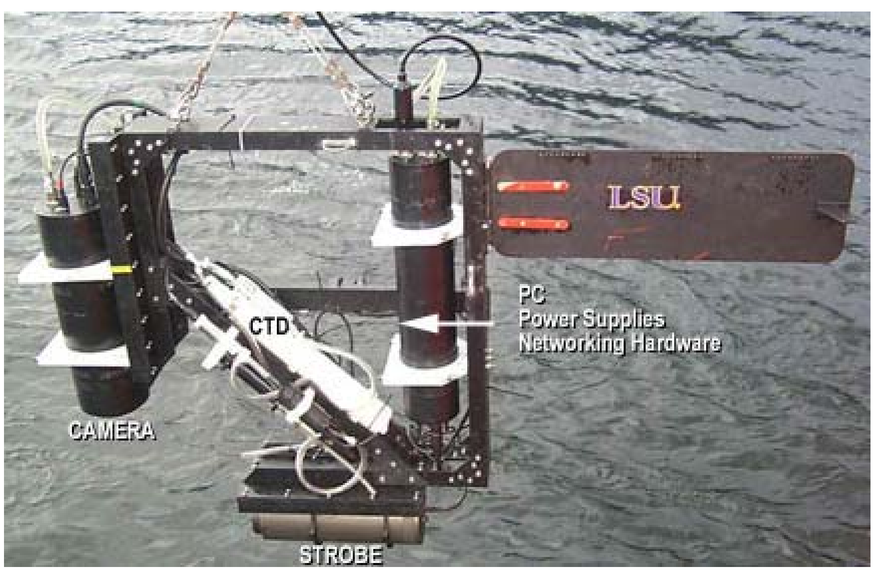

Figure 1: The ZOOVIS underwater vehicle prior to deployment in Knight Inlet illustrating the locations of the major sensor components.

WORK COMPLETED

Two field cruises have been completed during November in 2001 and 2002. Details of the data collected using the BIONESS, trawls and ADCP are summarized in a companion report by Mackas et al. while the acoustic results including the data provided by the new multibeam sonar are summarized by Trevorrow. ZOOVIS data were collected during day and night periods in proximity to the sill. ZOOVIS was primarily used to quantify the composition of intense scattering layers near the sill during the day and at the surface during the night. Its defined image volume allows the estimation of euphausiid abundances within scattering layers. We are currently working to reconcile the abundance estimates derived from BIONESS, acoustics, and ZOOVIS. The down-looking images permit us to estimate the in situ orientations of euphausiids, which can have an important influence on measured backscattering and my also provide insights into euphausiid behavior when they encounter the turbulent boundary layer near the sill. An undergraduate student is currently measuring how the length:width ratio and cross-sectional areas of preserved euphausiids change when imaged at different tilt angles. We will use these data to estimate orientation directly from the images. ZOOVIS abundance estimates have been completed for several surveys and the presence of large numbers of euphausiids in individual images has provided a means of calculating the distribution of nearest neighbor distances among euphausiids. This information will provide another means of predicting the maximum densities of euphausiids within dense patches.

ZOOVIS data from Knight Inlet have been presented in a poster at the PICES Zooplankton Production meeting in Gijon, Spain (June 2003), as an invited presentation at the 2003 Estuarine Research Federation meeting in Seattle (Sept 2003), and as a peer-reviewed book chapter (Benfield et al., 2003). Nearest-neighbor distance data will be presented at the 2004 Ocean Research Conference in Honolulu.

RESULTS

ZOOVIS collected striking images of euphausiids (Figs. 2,3) and other zooplanktors. Each cast was preceded by imaging a calibration target that allowed us to precisely quantify the dimensions of each image. Towards the end of the 2002 cruise we increased the image volume to 3.4 L and obtained a dataset containing images with multiple (up to 11 individuals). In the most intense sections of the acoustical scattering layers, euphausiid densities were estimated to exceed 2 L^{-1}. Nearest neighbor distances calculated from one ZOOVIS tow indicated that euphausiids had a mean separation distance of 14.3 cm (n=275 euphausiids, S.E.=0.4 cm, range = 0.78–32.03 cm). Most individuals were in a horizontal posture. Surveys conducted at night provided a fortuitous opportunity to measure the reactions of euphausiids to changes in ambient light when a deck light was switched on and measured scattering diminished dramatically and instantaneously. ZOOVIS images suggest that the euphausiids were responding to the lights by shifting from their normal horizontal orientation to a near vertical one. We are in the process of digitizing images representative of both orientation extremes to determine whether the reductions in predicted scattering associated with a horizontal to vertical shift in orientation is of sufficient magnitude to account for observed changes in scattering.

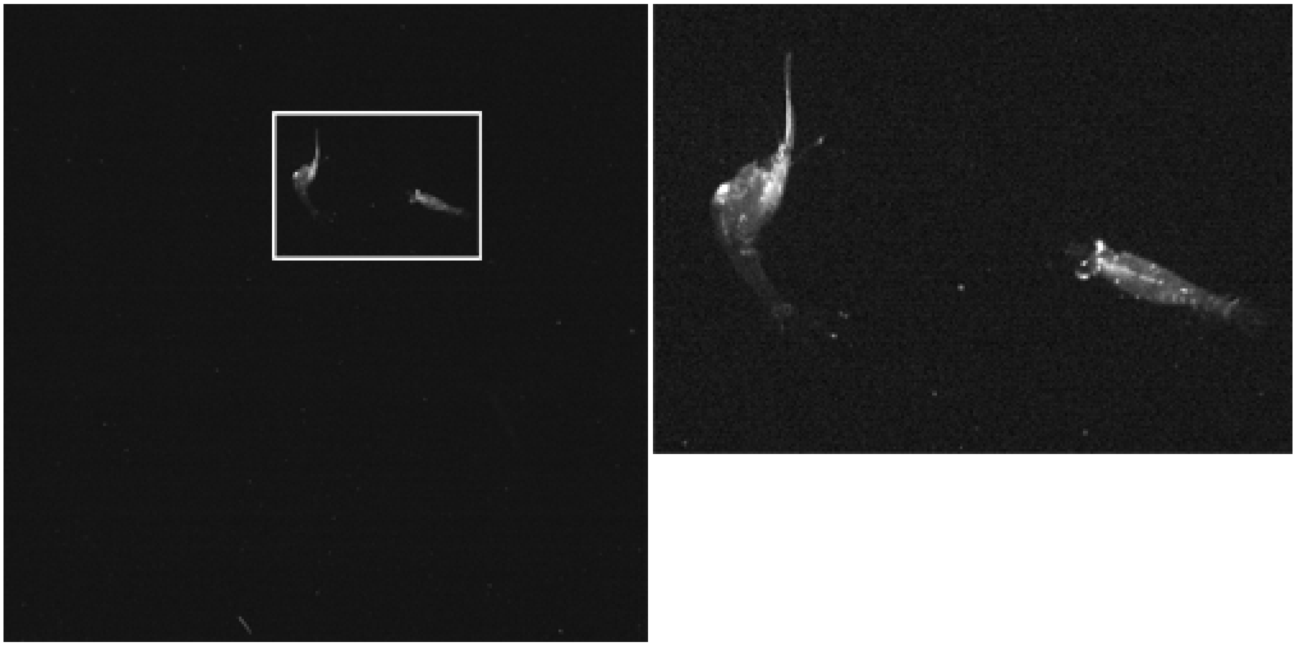

Figure 2. (Left): A ZOOVIS image containing 2 euphausiids approximately 1 cm in length. The image volume is 346 ml (10.6 cm wide x 10.6 cm tall x 3.1 cm deep). (Right): enlargement of the region containing the euphausiids to illustrate the resolution available within these images.

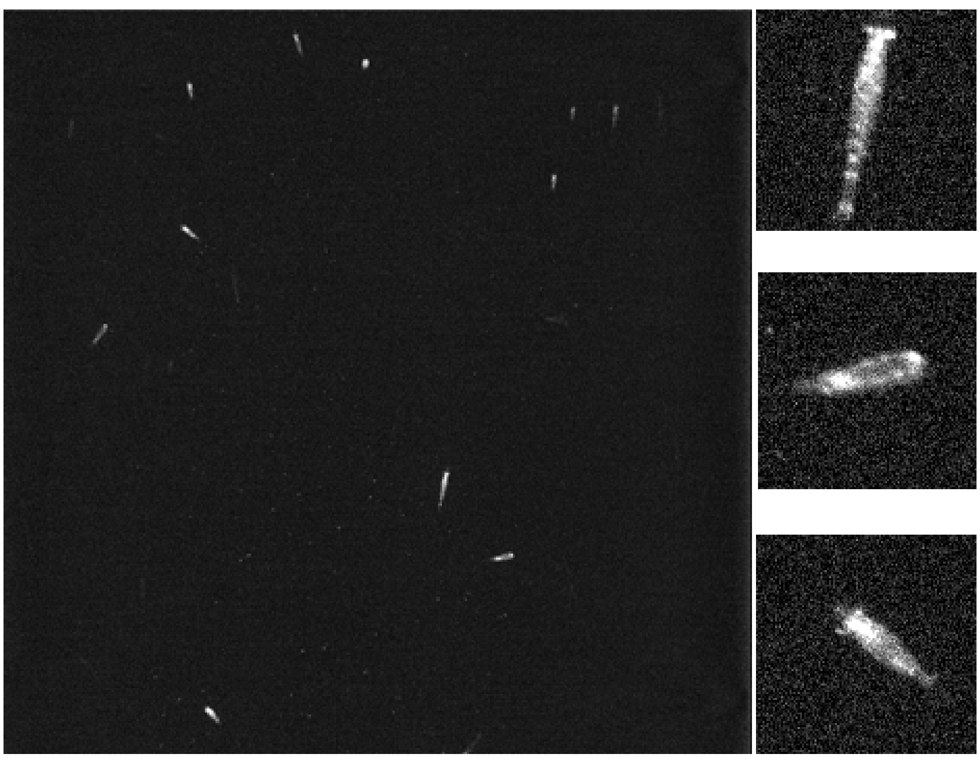

Figure 3. (Left): A ZOOVIS image containing 11 euphausiids. The image volume is 3407 ml (31.2 cm wide x 31.2 cm tall x 3.5 cm deep). (Right): enlargement of several of the euphausiids.

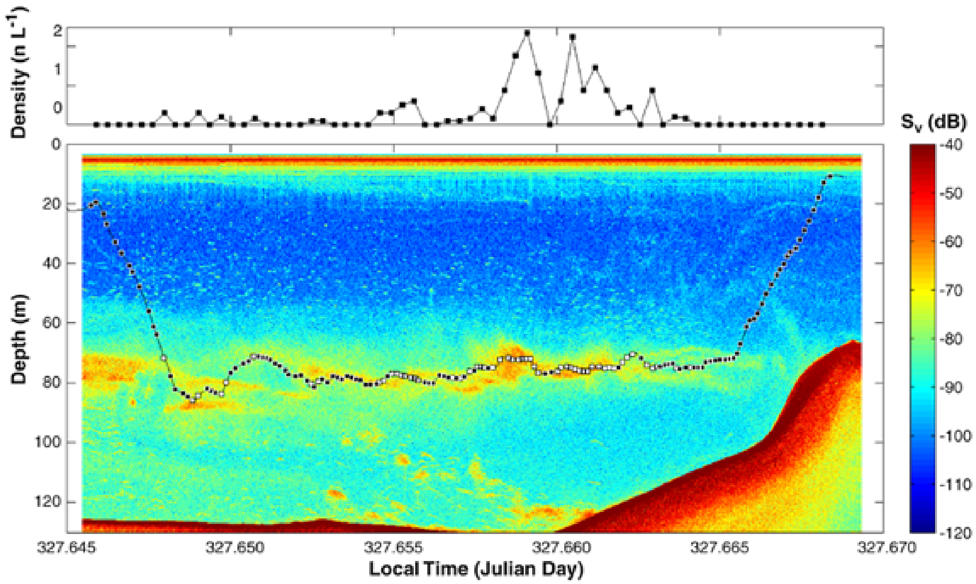

Figure 4. (Bottom): A ZOOVIS tow through an intense acoustical scattering layer near the sill during the day. Black squares indicate image locations. White squares designate images containing euphausiids. The upper panel is the density of euphausiids estimated from images. (Acoustic data provided by M. Trevorrow).

IMPACT/APPLICATIONS

This study demonstrated the importance and value of combining multifrequency acoustics with imaging optics and multinet samplers. ZOOVIS emerged as a powerful tool for mapping zooplankton distributions and recording their orientation. Its value was particularly evident when used in combination with acoustics, which provided a context from which to guide the camera and make the most effective use of wire time.

RELATED PROJECTS

This project is coupled with projects headed by D. Mackas from IOS and M. Trevorrow from DREA, with the common aim of understanding zooplankton aggregations at the Knight Inlet sill. D. Mackas is responsible for coordination of ship-time on the *CCGS Vector*, and along with his group at IOS for operation of an instrumented BIONESS trawl, an Otter trawl, and subsequent processing of the zooplankton samples. M. Trevorrow was responsible for the down-looking and multibeam echosounders. ZOOVIS images are a source of data for a related project (N00014-01-1-0305 and N00014-00-D-0122) conducted by D. McGehee, M.C. Benfield, C. Greenlaw, and D.V. Holliday. The objective of that study is to develop acoustic scattering models from high-resolution images of zooplankton using the DWBA scattering model and publicly available Matlab code.

PUBLICATIONS

Benfield, M.C., C.J. Schwehm, R.G. Fredericks, G. Squyres, S.F. Keenan, and M.V. Trevorrow. 2003. Measurement of zooplankton distributions with a high-resolution digital camera system. In, P. Strutton, and L. Seuront (eds.) Scales in Aquatic Ecology: Measurement, Analysis and Simulation. CRC Press, pp. 17-30.

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